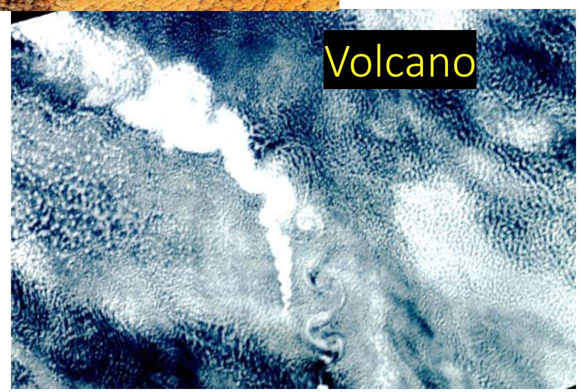
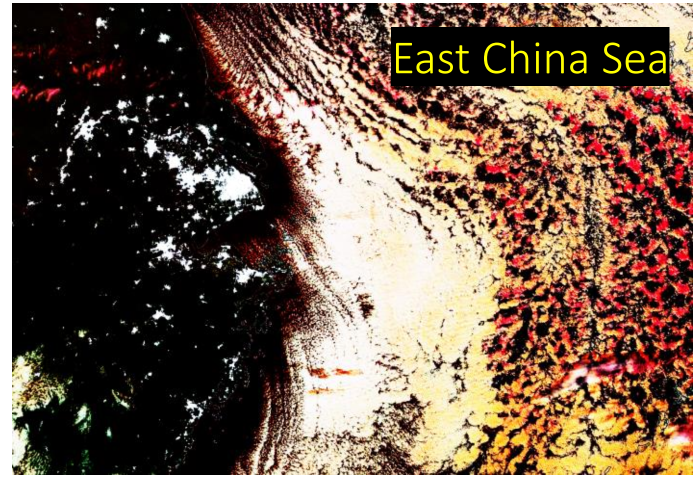
Weak average LWP response in polluted cloud tracks

Polluted cloud tracks induced by volcanoes, coal-fired power plants, oil refineries, smelters, fires and ohter localized pollution sources are detected in satellite images.





Polluted cloud areas are also detected downwind of larger industrial regions, covering hundreds-by-hundreds km.

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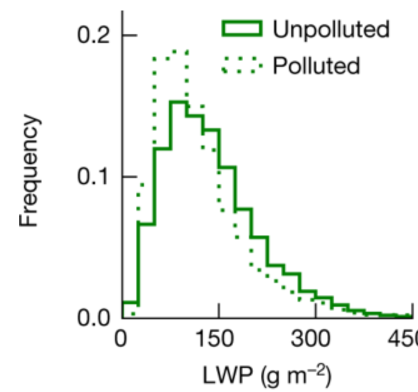
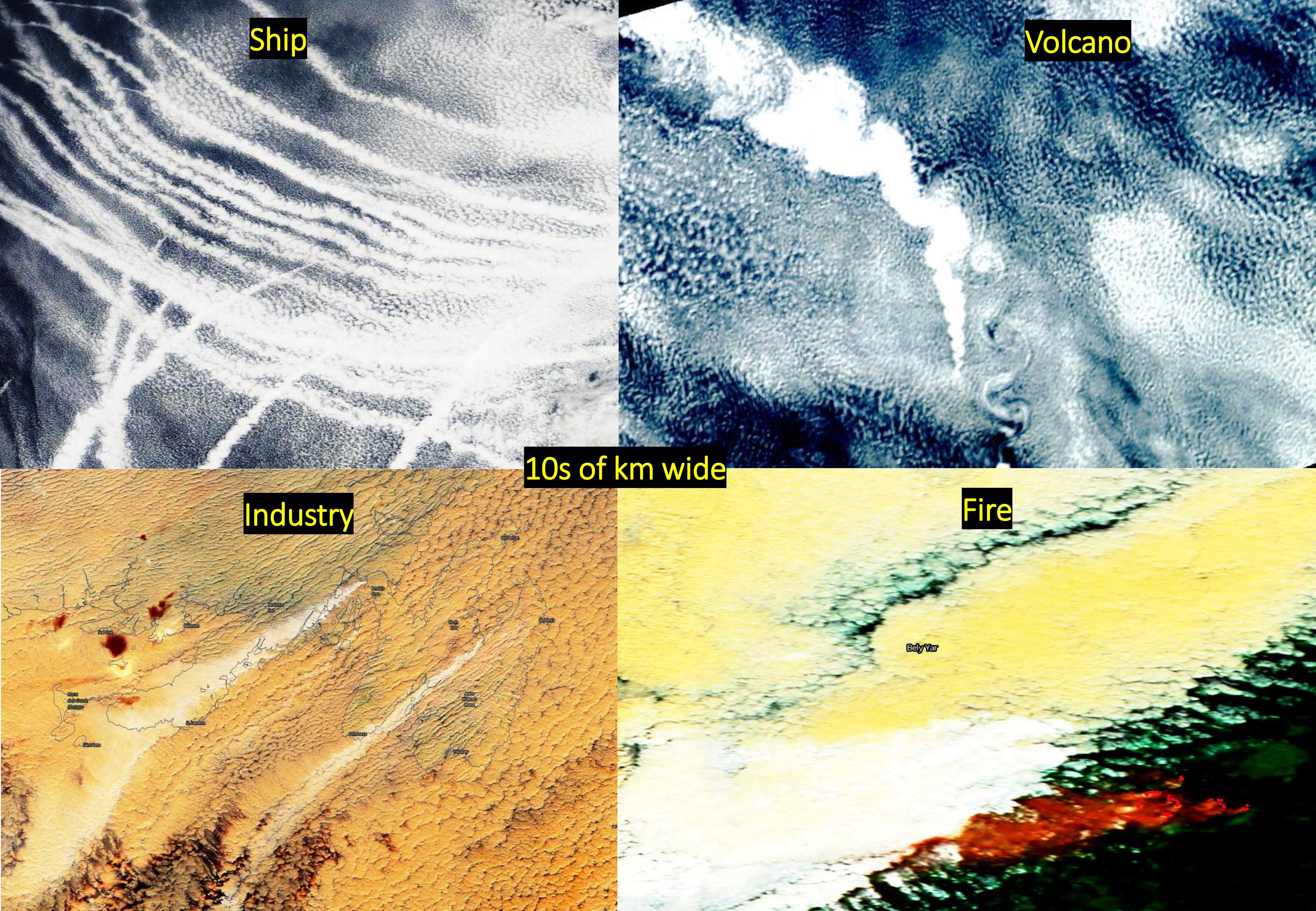
M.Christensen, J.Quaas, S.Gassó, H.Trofimov, J.Rahu, and N.Bellouin

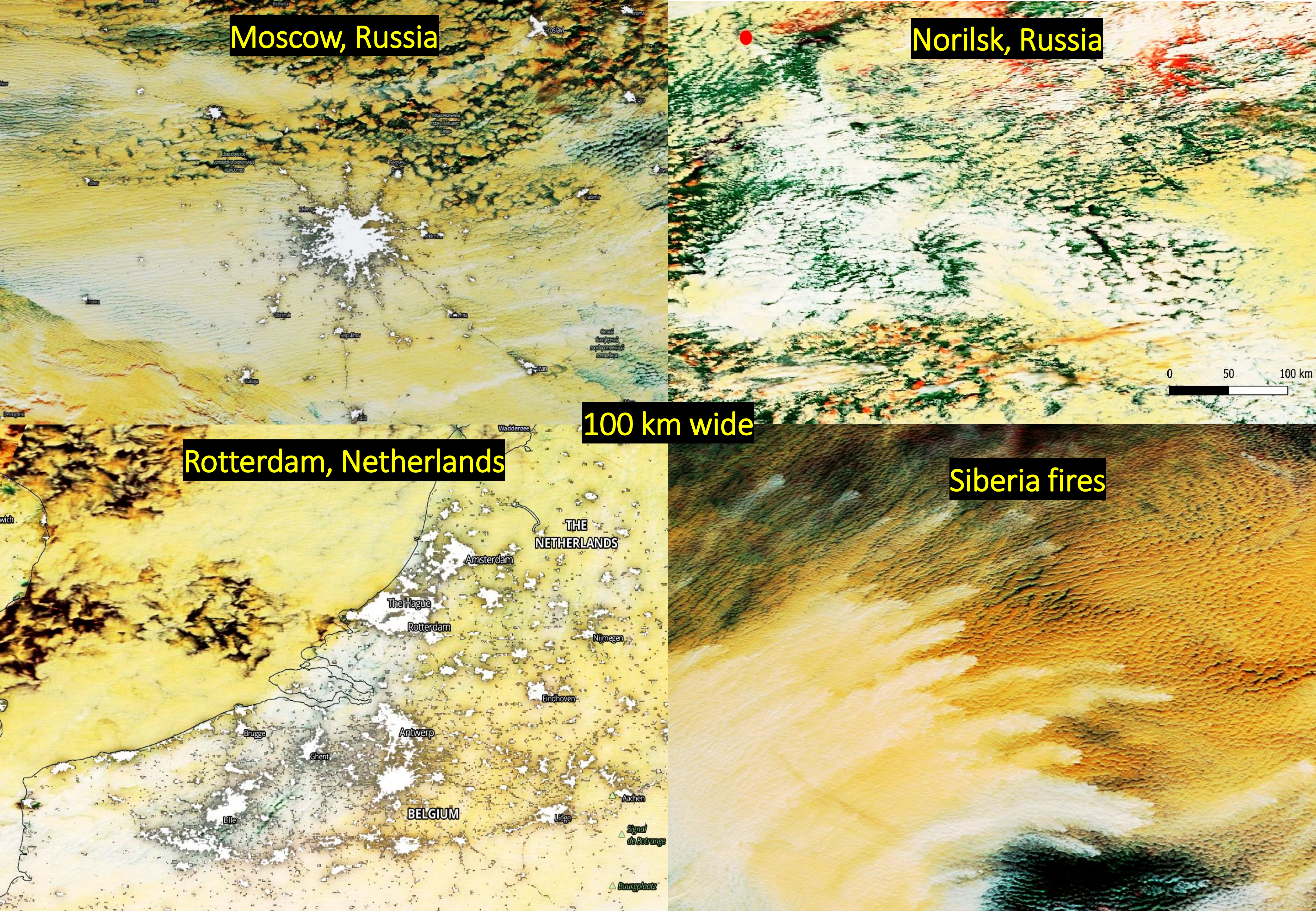
On average, there is relatively weak decrease in LWP in the polluted cloud tracks compared to the nearby unpolluted clouds.

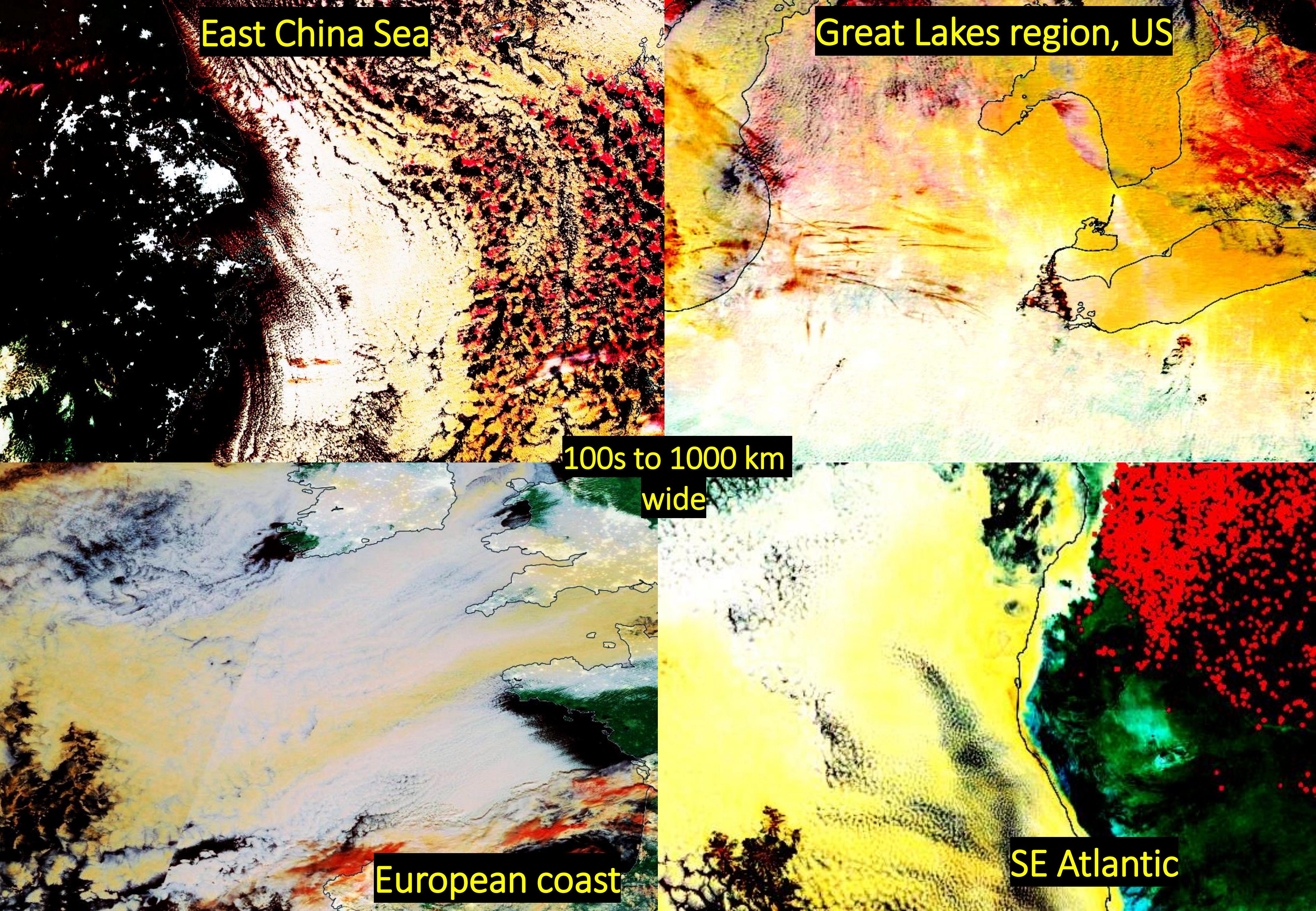


Toll et al 2017 *GRL* Toll et al 2019 *Nature*

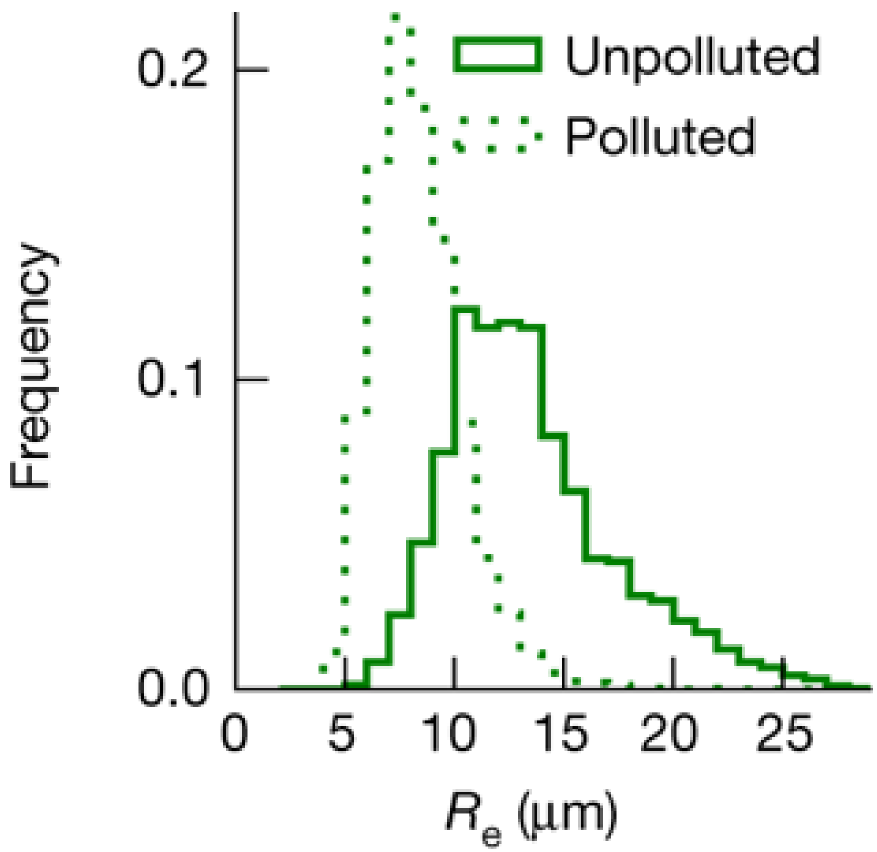
Trofimov et al 2020 *JGR*

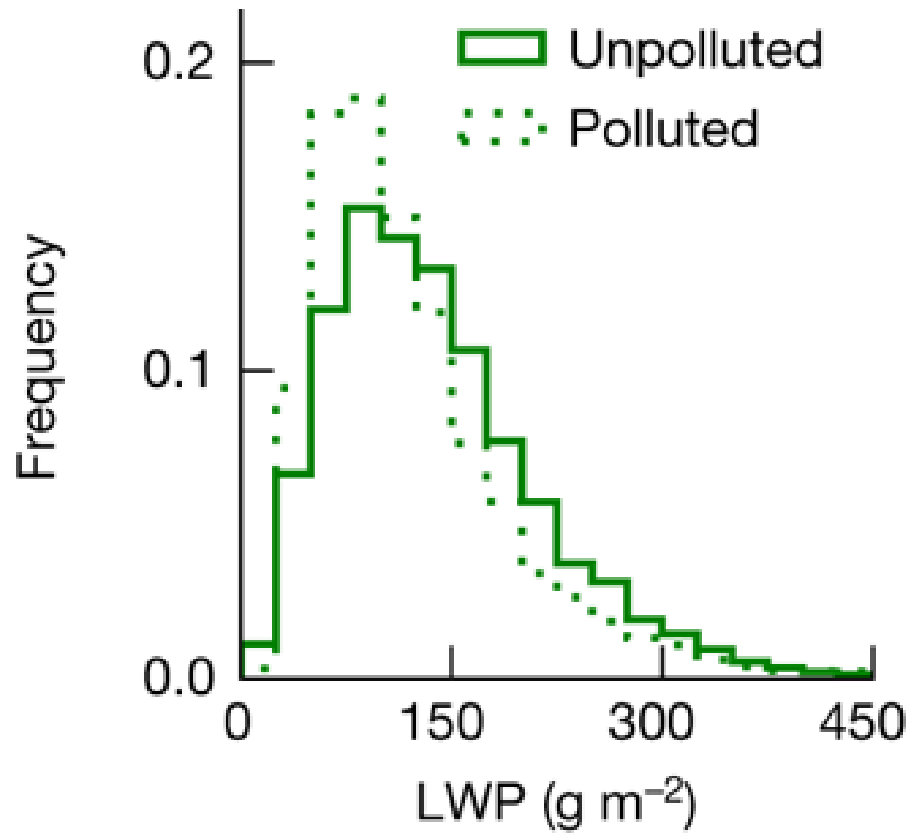

Ship
Volcano
10s of km wide
Industry
Fire
Bely Yar


Moscow, Russia
Norilsk, Russia
0 50 100 km
100 km wide
Rotterdam, Netherlands
Siberia fires
Waddenzee
THE NETHERLANDS
Amsterdam
The Hague
Rotterdam
Nijmegen
Eindhoven
Antwerp
Brugge
Ghent
BELGIUM
Lille
Liège
Aachen
Signal de Botrange


East China Sea
Great Lakes region, US
100s to 1000 km
wide
European coast
SE Atlantic

Weak LWP decrease on average: LWP increases are rather closely compensated by decreases

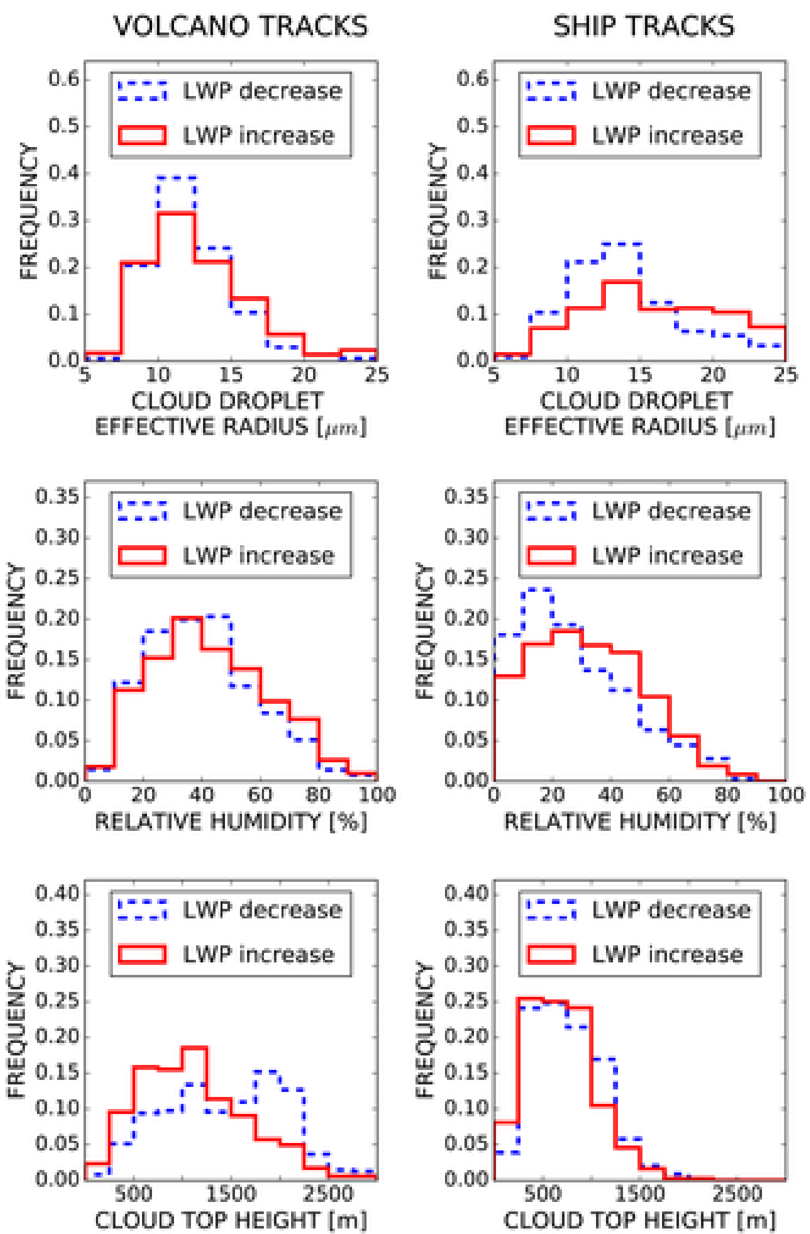




Comparison between polluted and unpolluted clouds using MODIS cloud product

Toll et al 2019 *Nature*

Meteorological dependence of LWP response



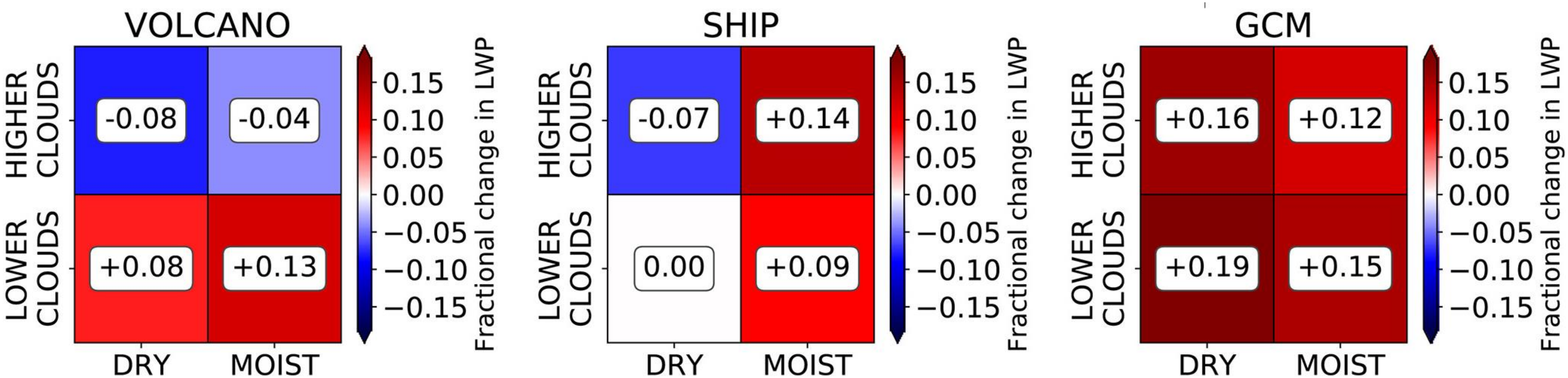
LWP response dependence on cloud droplet size supports suppression of precipitation.

LWP response dependence on relative humidity supports aerosol-enhanced entrainment.

There is a lot of variability in the responses under all conditions: processes controlling LWP increases and decreases need to be better understood.

Toll et al 2017 *GRL*

Unidirectional LWP increases in HadGEM3 GCM vs off-setting LWP increases and decreases in track observations

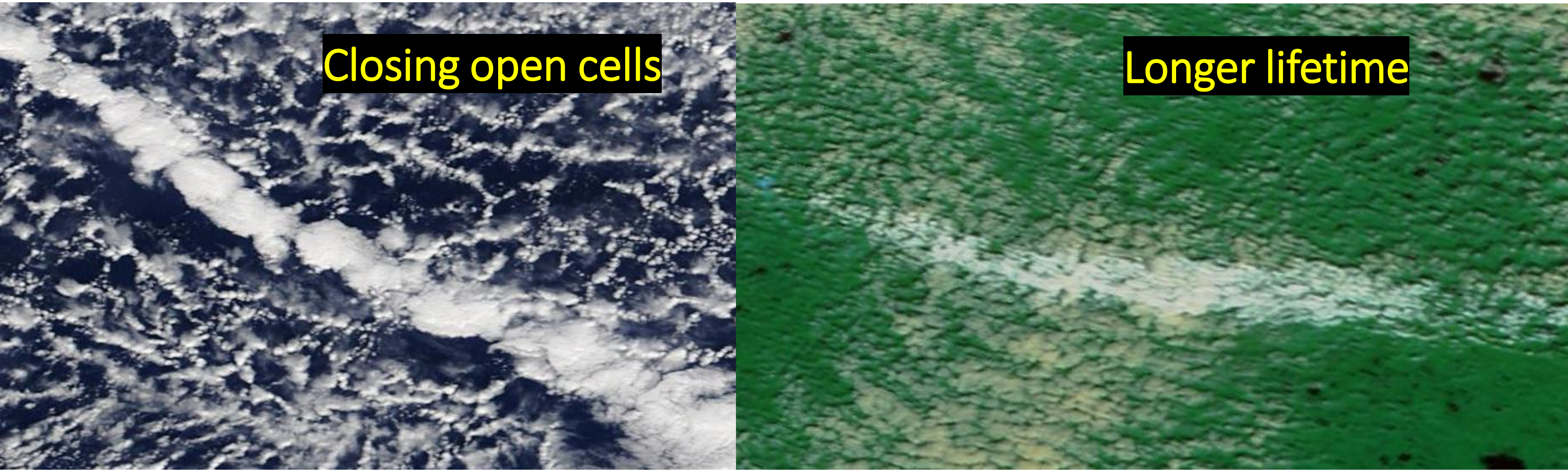


We can not rely on GCMs regarding the LWP response to aerosols.

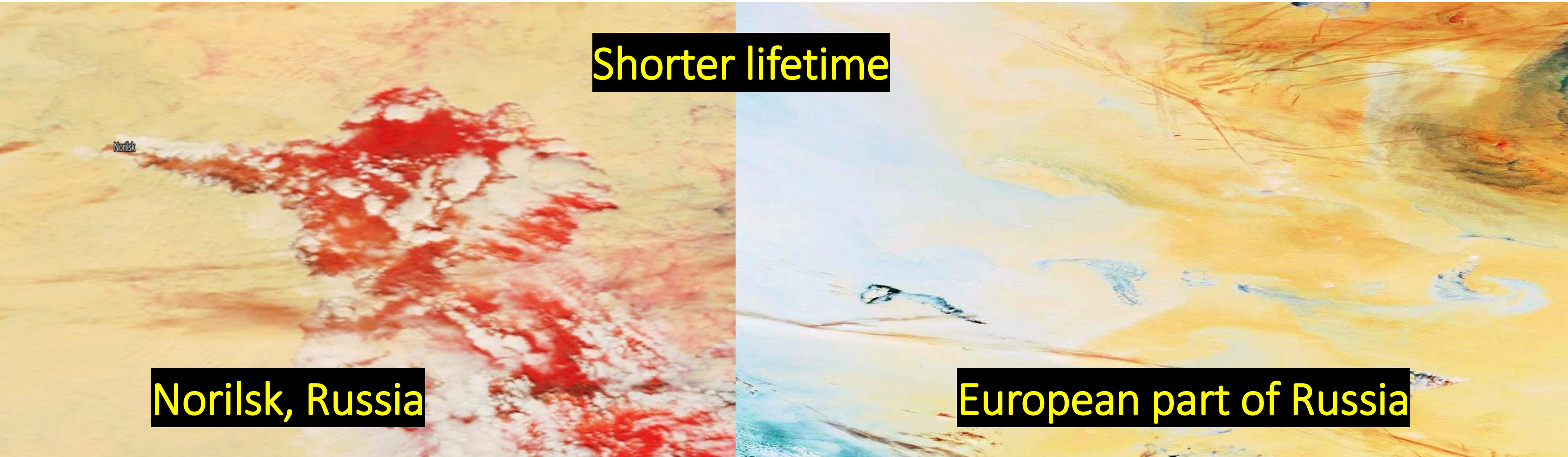
How to improve GCM parameterizations of 2nd aerosol indirect effect, can track observations help?

Toll et al 2017 *GRL*

Increased cloud fraction



Decreased cloud fraction



ON-OFF behaviour of strong aerosol perturbations

Fraction of track-days (of all days with liquid cloud cover)

Cherepovetz, Russia 37%

Thompson, Canada 20%

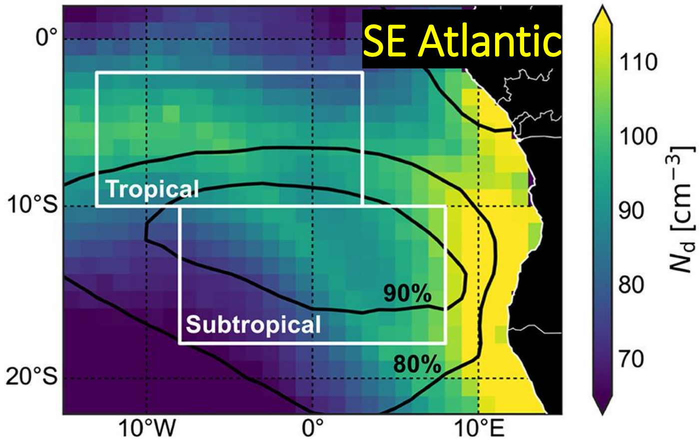
Norilsk, Russia 27%

Tracks and larger-scale anthropogenic cloud perturbations are not detected every day. Potential reasons: conditions favourable for particle formation and growth, vertical transport, liquid clouds susceptible to perturbations?

GCMs can not capture such complexity.

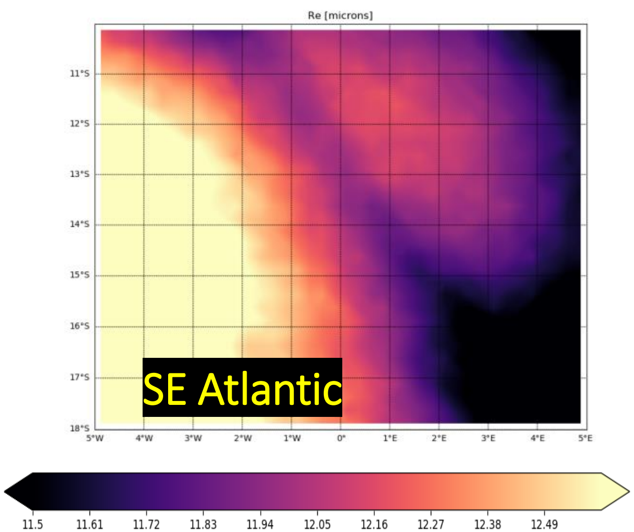
How large fraction of radiative forcing is caused by these strongest perturbations?

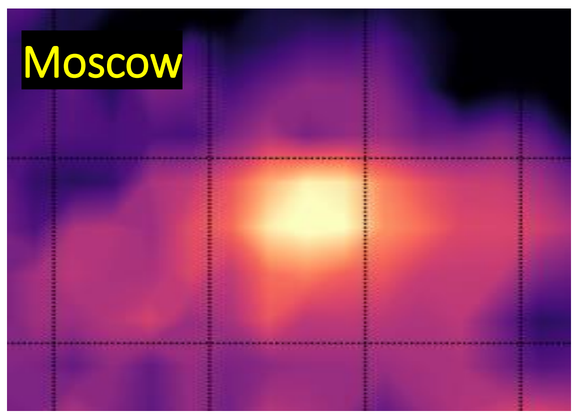
Polluted cloud tracks recorded in long-term average cloud properties

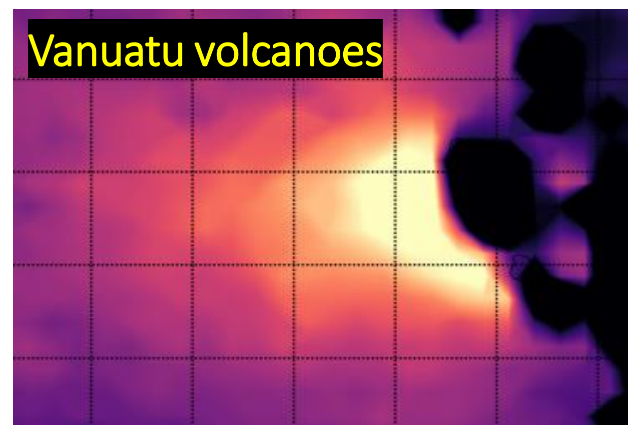


MODIS CDNC: Shipping corridor seen in the South-East Atlantic

Diamond et al 2020 AGU Advances







AVHRR Re data 1982-2015 at 0.25 deg resolution

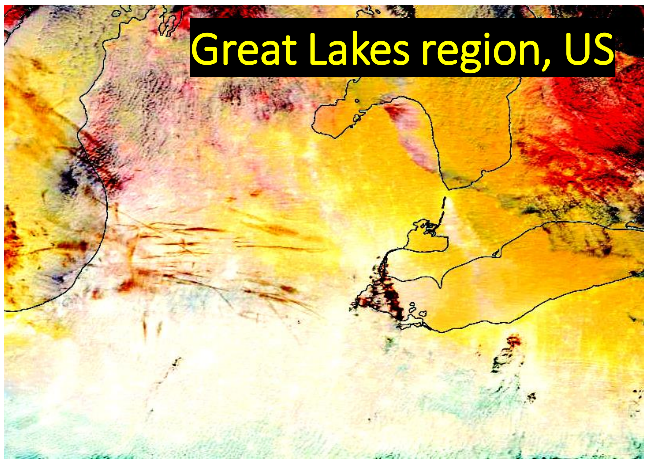
Discussion/Conclusions based on track observations

Relatively weak LWP decrease on average. This off-sets part of the Twomey effect.

Clear meteorological control of the LWP response. Is the suppressed collision-coalescence efficiency vs aerosol-enhanced entrainment sufficient explanation for LWP responses?

Other than open to closed cell transition, cloud fraction changes are rare.

Tracks are detected on 20% to 40% of days with liquid cloud cover.



Can GCMs capture such spatial contrasts?

Are such observations useful to constrain cloud responses to aerosols in GCMS?